

FORM PTO-1390 (REV 11-98)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 922-122
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) <b>09/744 818</b> Unknown
INTERNATIONAL APPLICATION NO. <b>PCT/GB99/02160</b>	INTERNATIONAL FILING DATE <b>6 July 1999</b>	PRIORITY DATE CLAIMED <b>15 July 1998</b>
TITLE OF INVENTION <b>DIAGNOSTIC SENSOR</b>		
APPLICANT(S) FOR DO/EO/US <b>GALLAGHER</b>		

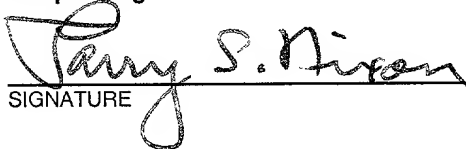
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

- ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
- ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
- ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
- ☒ A proper Demand for International Preliminary Examination was made by the 19<sup>th</sup> month from the earliest claimed priority date.
- A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
  - ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - ☒ has been transmitted by the International Bureau.
  - ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
- ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
- ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
  - ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - ☐ have been transmitted by the International Bureau.
  - ☐ have not been made; however, the time limit for making such amendments has **NOT** expired.
  - ☐ have not been made and will not be made.
- ☐ A translation of the amendments to the claims under PCT Article 19 (U.S.C. 371(c)(3)).
- ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
- ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

**Items 11. To 16. Below concern document(s) or information included:**

- ☐ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98.
- ☐ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included.
- ☒ A **FIRST** preliminary amendment.  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
- ☐ A substitute specification.
- ☐ A change of power of attorney and/or address letter.
- ☒ Other items or information. **Petition Under Rule 1.137(b) to Revive Unintentionally Abandoned Application, PTO-1449 and copy of International Search Report**  
☒ This application is entitled to "Small entity" status. ☐ "Small entity" statement attached.



U.S. APPLICATION NO. <b>69/144818</b> Unknown		INTERNATIONAL APPLICATION NO <b>PCT/GB99/02160</b>		ATTORNEY'S DOCKET NUMBER <b>922-122</b>	
17. <input checked="" type="checkbox"/> The following fees are submitted:				<b>CALCULATIONS</b> PTO USE ONLY	
<b>BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5):</b> -- Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .....\$1000.00 -- International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .....\$860.00 -- International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but international search fee (37 C.F.R. 1.445(a)(2)) paid to USPTO .....\$710.00 -- International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) .....\$690.00 -- International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) .....\$100.00  <div style="text-align: right;"><b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b></div>				<div style="border: 1px solid black; padding: 2px;">\$ 860.00</div>	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				<div style="border: 1px solid black; padding: 2px;">\$ 0.00</div>	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	10	-20 = 0	X \$18.00	\$ 0.00	
Independent Claims	2	-3 = 0	X \$80.00	\$ 0.00	
MULTIPLE DEPENDENT CLAIMS(S) (if applicable)			\$270.00	\$ 0.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ <b>860.00</b>	
Reduction by 1/2 for filing by small entity, if applicable. Small entity status must also be asserted. (Note 37 C.F.R. 1.9, 1.27, 1.28).				430.00	
<b>SUBTOTAL =</b>				\$ <b>430.00</b>	
Processing fee of \$130.00, for furnishing the English Translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 C.F.R. 1.492(f)).				0.00	
<b>TOTAL NATIONAL FEE =</b>				\$ <b>430.00</b>	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). <b>\$40.00</b> per property				\$ 0.00	
Fee for Petition to Revive Unintentionally Abandoned Application (\$1240.00 - Small Entity = \$620.00)				\$ 620.00	
<b>TOTAL FEES ENCLOSED =</b>				\$ <b>1050.00</b>	
				Amount to be: refunded \$	
				Charged \$	
a. <input checked="" type="checkbox"/> A check in the amount of \$1050.00 to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. 14-1140 in the amount of \$_____ to cover the above fees. A duplicate copy of this form is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 14-1140. A duplicate copy of this form is enclosed. d. <input type="checkbox"/> The entire content of the foreign application(s), referred to in this application is/are hereby incorporated by reference in this application.					
<b>NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>					
<b>SEND ALL CORRESPONDENCE TO:</b>  NIXON & VANDERHYE P.C. 1100 North Glebe Road, 8 <sup>th</sup> Floor Arlington, Virginia 22201 Telephone: (703) 816-4000					
				 SIGNATURE	
				<b>Larry S. Nixon</b> NAME	
				<b>25,640</b> REGISTRATION NUMBER	
				<b>January 30, 2001</b> Date	

JC07 Rec'd PCE/PTO 30 JAN 2001

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DIAGNOSTIC SENSOR

This invention is concerned with the use of a vibrating resonant structure for the measurement of physical and chemical properties of fluids and solids.

It is known to measure an attribute such as the density or viscosity of a medium, whether solid or fluid, by measuring some characteristic or parameter of vibration of a vibratile structure. Some examples which illustrate the general state of the art are shown in US Patents 5023560, 5363691 and 5670709.

The present invention is based on measuring vibration of amplitude, phase or frequency of a mechanical resonator as a result of a change in modal shape of a resonant system, caused for example by a change in stiffness of a beam element which form part of or is coupled to the resonator.

Brief Description of the Drawings

Figures 1 and 2 illustrate beam resonators various resonant systems.

Figures 3 and 4 illustrate various resonant characteristics.

Figures 5 to 8 illustrate various beam resonators

Figure 9 illustrates a particular embodiment of the invention (Figure 9A) and characteristics of its resonant modes (Figure 9B).

Figure 10 illustrates a resonant characteristic;

Figure 11 illustrates another embodiment of the invention.

Figure 12 illustrates another embodiment of the invention

Figure 13 illustrates the embodiment shown in Figure 12 but vibrating in a different mode.

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Figure 14 and 15 illustrate the change of a resonator from a 'clamped-pinned state to-a 'clamped-free' state

### Detailed Description

Various embodiments are described by way of example to illustrate the principles employed in the invention

Figure 1 illustrates a beam resonator 10 comprising two substantially parallel beams 10a and 10b which are rigidly connected at their extremities. The connections of the beams at their extremities are substantial and yokes 11 and 12 thus formed at the extremities have a high stiffness. The beams are therefore referred to, in the terminology of modal beam analysis, as 'clamped'. The vibration of the beams is denoted by the arrows Y.

Such a resonator, referred to herein as 'clamp-clamp', will resonate at a first mode natural frequency given by the equation:

$$f = 22.3733 \sqrt{(EI/ML^4)} \dots \dots \dots (1)$$

f = Frequency

E = Young Modulus

I = Mass Moment of Inertia

M = Mass/Unit Length

L = Beam Length

If the connecting yoke 11 at one end of the resonator 10 is substantially weakened the beams can no longer be considered clamped, as they are allowed a degree of rotation about their connection point; in the terminology of modal beam analysis the yoke is then approaching the 'pinned' condition. This condition is shown in Figure 2, and the 'clamp-pinned' system will now resonate at a natural frequency given by the equation:

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$$f = 15\,4182 \sqrt{EI/ML^4} \quad (2)$$

From equations (1) and (2) it can be seen that the transition from fully clamped to fully pinned results in an approximately 30% change in frequency. If the yoke connection is lost the beams are referred to as 'free', and the clamped-free system now resonates at a natural frequency given by the equation.

$$f = 3.516 \sqrt{EI/ML^4} \quad (3)$$

From equations (2) and (3) it can be seen that the transition from fully pinned to fully free results in an approximately 77% change in frequency.

In addition to a change in frequency, the modal shape of the clamp-clamp system differs significantly to that of the clamp-pinned arrangement. A generalised view of the displacement of the beam in clamped and pinned mode is shown in Figure 3. The curve 30 illustrates the variation in maximum displacement of the beam over its length when the yokes 11 and 12 are 'clamped'. The curve 31 illustrates the corresponding displacement when the yoke 11 is 'pinned'. Figure 4 shows the variation of local beam bending with respect to position along the beam for the clamp-clamp state (curve 40) and the clamp-pinned state (curve 41). There are further modal changes as the clamp-pinned condition progresses to clamped-free.

A sensor, such as a piezoelectric device, responding to localised beam flexure would exhibit a signal response with position along the length of the beam in a manner similar to the profiles shown in Figure 4. As well as a voltage amplitude variation with length there can also be observed a polarity change, or phase change, of the vibration signal along the length.

In summary, the transition from a clamp-clamp state to a clamp-pinned state, or from a clamp-pinned state to a clamp-free state results in changes in frequency, amplitude and phase of vibration relative to position on beam. It also follows that a change from clamp-clamp to clamp-free will obviously have a similar result. The measurement of change of these parameters in response to an event influencing the modal classification of the resonator (e.g. clamp-clamp

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to clamp-pinned, clamp-pinned to clamp-free) forms the basis of this invention

In applications where there is depletion of a substance or build-up of material, such as corrosion or scaling, the actual substrate may form a stiffening member on the beam yoke and thus contribute to the status of the yoke as clamped or pinned

Figure 5 shows a simple embodiment of a dual beam system, similar to that shown in Figure 1. Depletion of material at the connection of the beams forming yoke 11 produces a thinner, less substantial connection as shown at 13 in Figure 5 and can produce a change to a pinned state at this end of the resonator. However in general such a system would require significant depletion of material to manifest a modal change.

Improvements on this basic system are shown in Figure 6 and Figure 7; in both these cases the simple connection yoke 11 is replaced by a box section 15. The section achieves its stiffness from the spatially separated members 14 and 14a, and a small reduction of thickness of a part of either member 14, 14a will manifest a substantial change in rigidity - thus altering the stiffness of the section

Figure 6 particularly shows a system where in the rigidity of the box section is modulated by the longitudinal stiffness of the member 14. Figure 7 shows the segments 16 and 17 between the members 14 and 14a, they will significantly influence the rigidity of section 15 if their flexural or longitudinal stiffness is altered.

Figure 8 shows a refinement of the system in Figure 6 and allows for a 'bolt-on' section stiffener 18 to be used to join the beams at the end in place of member 14. The stiffener 18 is secured by bolts 19 to each of the beams 10a and 10b. This forms a convenient means of selecting the material, shape and size of a section member to suit a particular application

Figure 9A illustrates a specific embodiment based on the system shown in Figure 8, although in principle any of the systems previously described could be used. Piezoelectric transducers are strategically placed to indicate the amplitude and phase of the flexure of the beam at a specific

location The signal from each transducer relates directly to the modal pattern formed by the clamp or pinned condition of the yoke Lateral vibration of the beam structure is shown by the arrows Y

5 In the system shown in Figure 9A, piezoelectric transducers 21, 22 and 23 are disposed at different locations along the inner surface of the lower beam 10b in order to obtain a measure, represented by the relevant piezo output voltage, of the displacement of the beam at those locations when the system is in a resonant vibratory mode induced by a drive piezoelectric transducer 24 disposed (in this example) at the clamped end of the resonant beam system. In this system the transducer 23 acts as a reference, because it is located close to a node and the displacement of the adjacent part of the resonator is minimal The drive transducer 24 may have a regenerative feedback connection (known per se in the art) from one or more of the sensing transducers 21, 22 or 23. Electromagnetic drive and sensing transducers may be used in place of piezoelectric transducers. Other forms of transducer, such as capacitive, optical or acoustic transducers may be used as appropriate.

10 Figure 9B is a graph of piezo voltage against distance measured along the beam, the curves 90 and 91 being for the clamped and pinned condition respective at the end 11. The particular piezo voltages are given by the intersections of the projection lines 21, 22a and 23a (through  
15 respective transducers 21, 22 and 23) with the curves 90 and 91

20 The embodiment shown in Figure 9 includes an enclosure 93 for the sensor, the enclosure comprising a tube which has a gland 94 for wires to pass to the transducers through a closed end of the tube. O-ring seals 95 and 96 are disposed between the beam structure 10 and the tube near the ends of the tube, from the open end of which the box section 15 protrudes.

25 Figure 10 illustrates the variation of the piezoelectric voltages  $V_a$  and  $V_b$ , from the sensors 21 and 22 (curves 101 and 102) and the frequency of resonance (curve 103), as a function of the decreasing stiffness of the section stiffener 18. Curve 101 exhibits a phase change (shown at 104) The curve 100 shows the substantially constant piezo voltage  $V_{ref}$  obtained from the transducer 23 It follows that the progress of any physical, chemical, or biological effect leading to the depletion or build-up of the sacrificial section stiffener material can be monitored by



measuring the modulation or variation of these piezoelectric sensor signals over time. As an example, a section stiffener made from iron will have its thickness, and hence its stiffness depleted, in a corrosive environment over time and measurement of  $V_a$ ,  $V_b$  or frequency will indicate the rate of corrosion. It further follows that selection of other materials in the electrochemical series can exhibit the same corrosion/deposition effects in the appropriate electrolyte or reactive medium.

Signal processing techniques, such as the following, can be employed to enhance the result:

- (a) Division of  $V_a$  by  $V_b$  will result in a ratio dependent on section stiffness but independent of amplitude of signals or system damping.
- (b) Division of  $V_a$  or  $V_b$  by  $V_{ref}$  will result in a ratio dependent on section stiffness but independent of amplitude of signals or system damping.
- (c) Measurement of phase of  $V_b$  will form a simple method of indicating the point at which a specific section stiffness is reached.
- (d) A plurality of piezoelectric sensor mounted along the beam can be monitored for change of phase to indicate progress of change of section stiffness.
- (e) If the resonator is at full temperature equilibrium with its environment the modal shape will indicate section stiffness independently of temperature.
- (f) Frequency signal has some temperature dependency so comparison of modal shape with frequency signal will yield both temperature and section stiffness from a single resonator.

In general terms the invention can provide a force transducer. With the section stiffener removed as shown in Figure 11 (which otherwise resembles Figure 9) the stiffness of the pinned yoke will be altered towards the clamped state by the presence of external forces 111, 112 on the yoke, either in compression or tension. These forces can be mechanical, electrical or

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magnetic

The movement of the beams 10a and 10b will create a velocity and therefore a shear action within a fluid. By measuring energy loss, or the quality factor Q, of the signal the viscous shear loss can be determined, and thus the fluid viscosity. Similarly, the damping capacity of any solid connected to the yoke can be determined from the Q of the resonant signal.

The elastic properties of a viscoelastic fluid can be derived from the change in resonant frequency due to the stiffening of the yokes as a result of the elastic modulus of the fluid.

Figure 12 illustrates sectionally a different embodiment in which the beam structure 10 comprises an internal cylindrical beam 120 and an external cylindrical beam 121. The beams are connected by a relatively thick yoke member 122 at a 'clamped' end and by a yoke member 123 at the other end. Reduction of the stiffness of this yoke 123 changes the connection at this end from 'clamped' to 'pinned'.

Figure 12 includes sensing transducers 21, 22 and 23 disposed on the external beam and a drive transducer 24 disposed on the yoke member 122. The beam structure is enclosed by a tube 93 which has a gland 94 and intermediate O-ring seals 95 and 96.

Figure 13 is similar to Figure 12 but illustrates vibration of the structure in a longitudinal mode (arrow X).

As a further example, Figure 14a and 14b shows the degeneration of a clamp-pinned structure 10 shown in Figure 14a to the clamp-free condition as the member 11 at one end vanishes. The structure is clamped at its other end 140.

All the resonators can be operated in harmonic modes above the natural frequency. There are proportional movements in modal/frequency behaviour at higher modes than a fundamental mode.

CLAIMS

1 A sensor comprising a mechanical resonator (10) including an element (11; 18; 123) of  
which the stiffness at least partially determines a modal shape of the resonance of the resonator  
and means (21-23) for measuring a variation of a measure of the resonance as the stiffness of  
said element changes.

2 A sensor according to claim 1 wherein the resonator (10) comprises two beams (10a, 10b,  
120, 121) connected by at least said element.

3 A sensor according to claim 2 wherein said beams are connected at or near one end by a  
yoke (12; 122) which provides a clamped condition of the resonator at said one end and are  
connected at or near another end by said element.

4. A sensor according to claim 3 wherein the resonator including said beams includes a box  
section disposed to increase the sensitivity of the resonator to changes in thickness of said  
element

5 A sensor according to any foregoing claim wherein said means for measuring (21-23)  
includes at least two sensing transducers of which one is located at or near a node of the  
resonance and provides a reference signal.

6 A method of sensing comprising measuring variation of amplitude or phase or frequency of  
a part of a resonator as a result of a change in modal shape of the resonator caused by a change  
in stiffness of an element forming part of or coupled to the resonator.

7. A method of sensing according to claim 5 and employed to detect the depletion or building  
of said element.

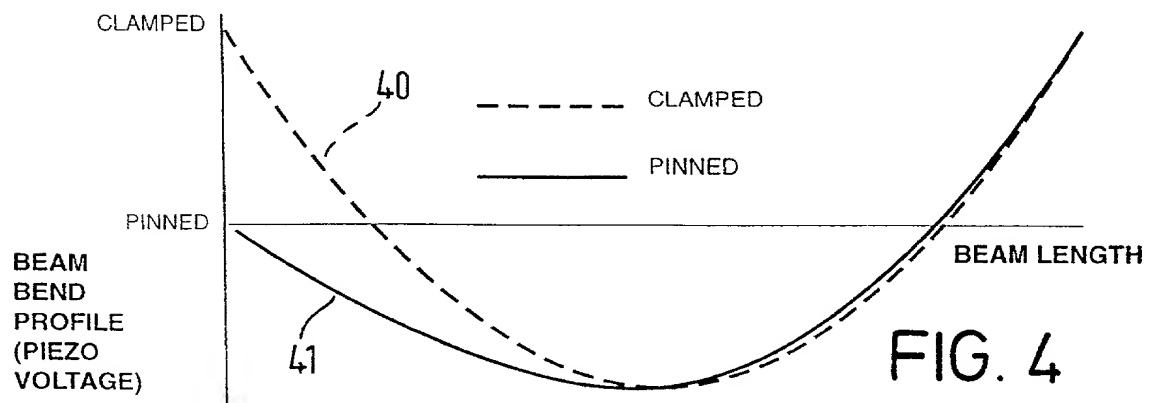
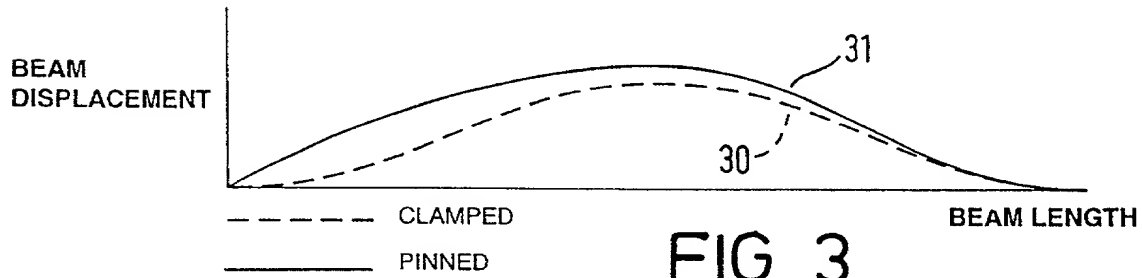
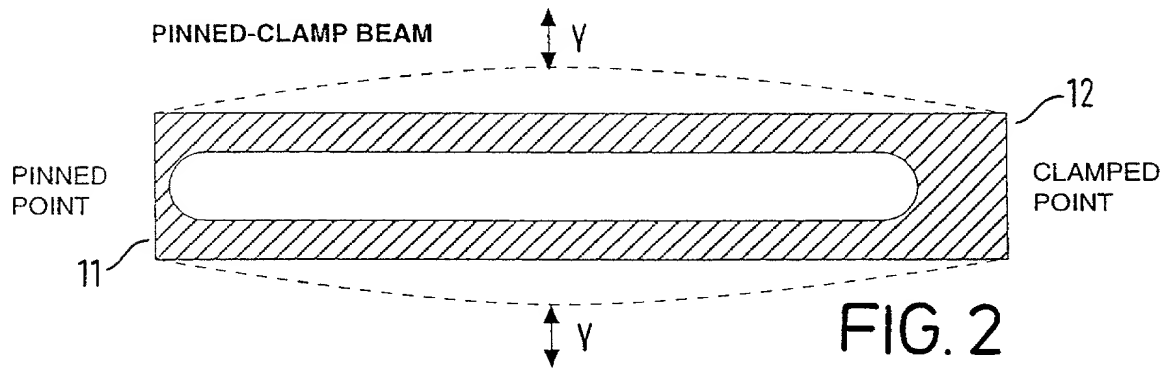
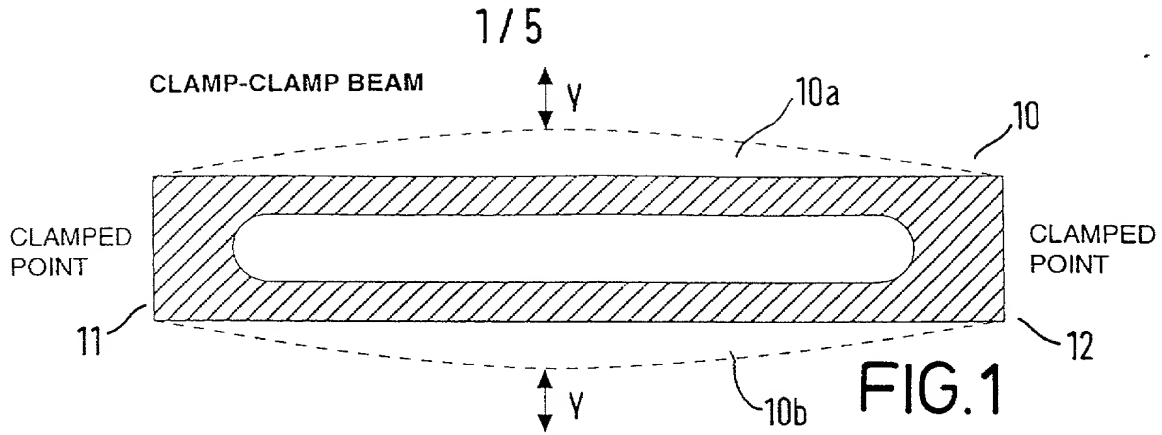
8 A method according to claim 5 and employed to measure the viscosity of a fluid

9. A method according to claim 5 and employed to measure the viscoelasticity of a solid or

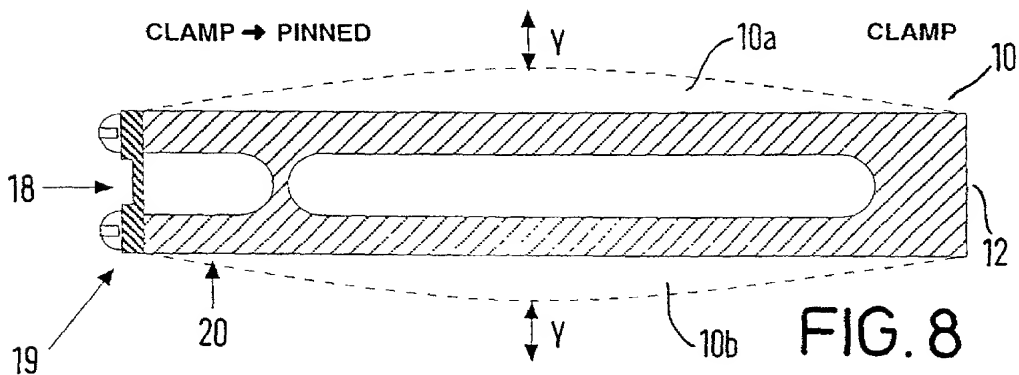
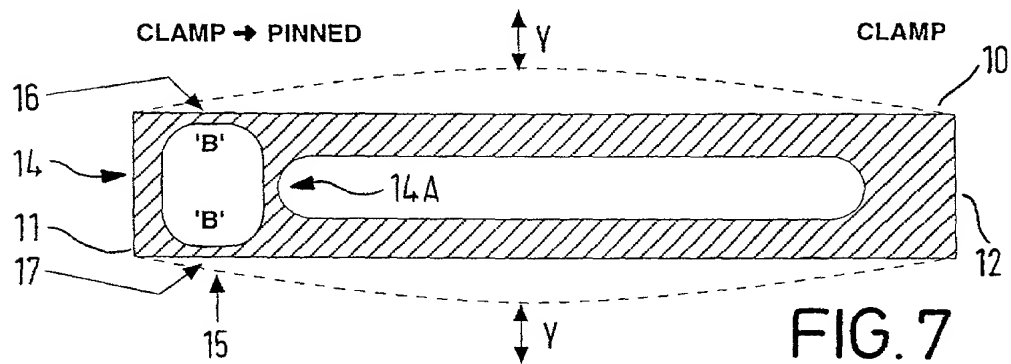
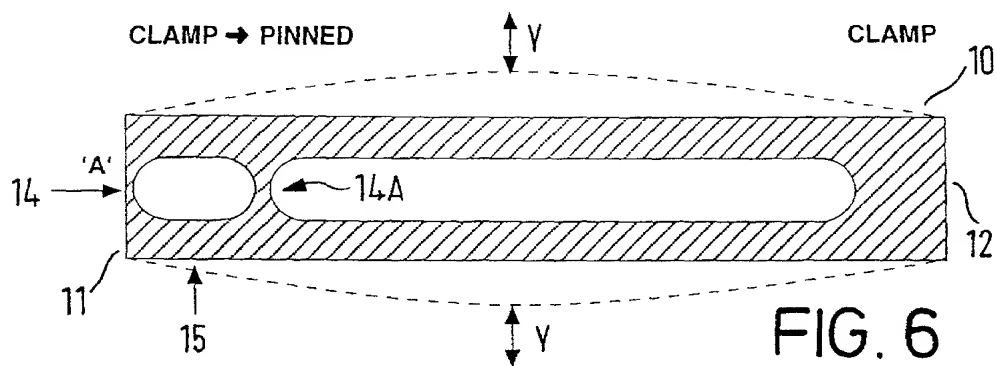
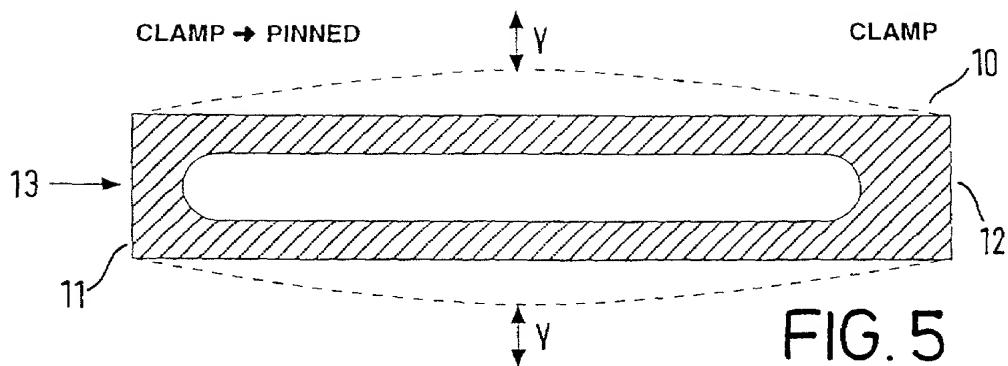
fluid

10 A method according to claim 5 and employed to measure force from a change in modal shape of the resonator

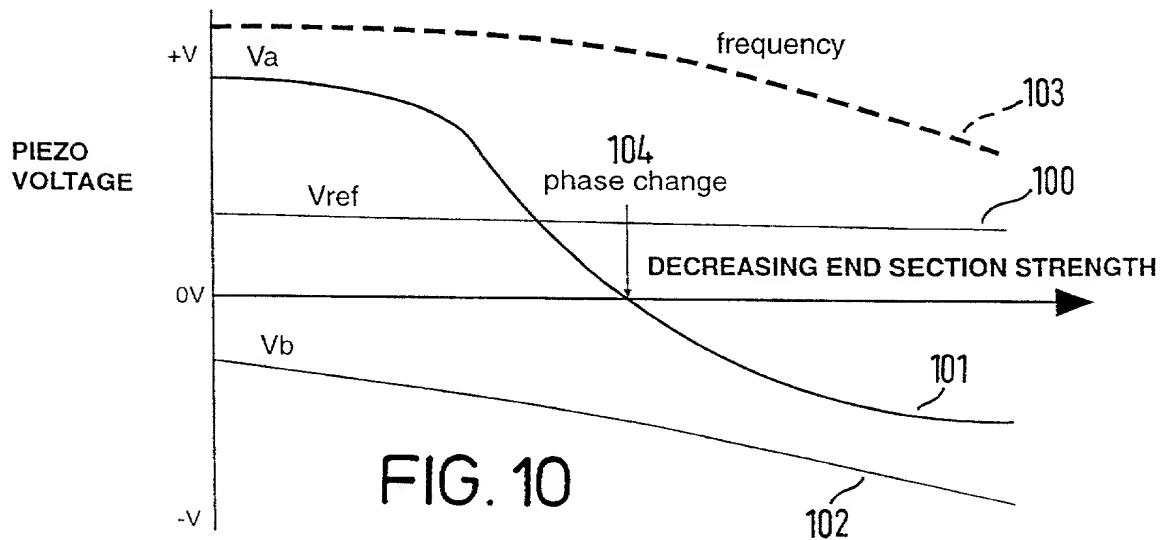
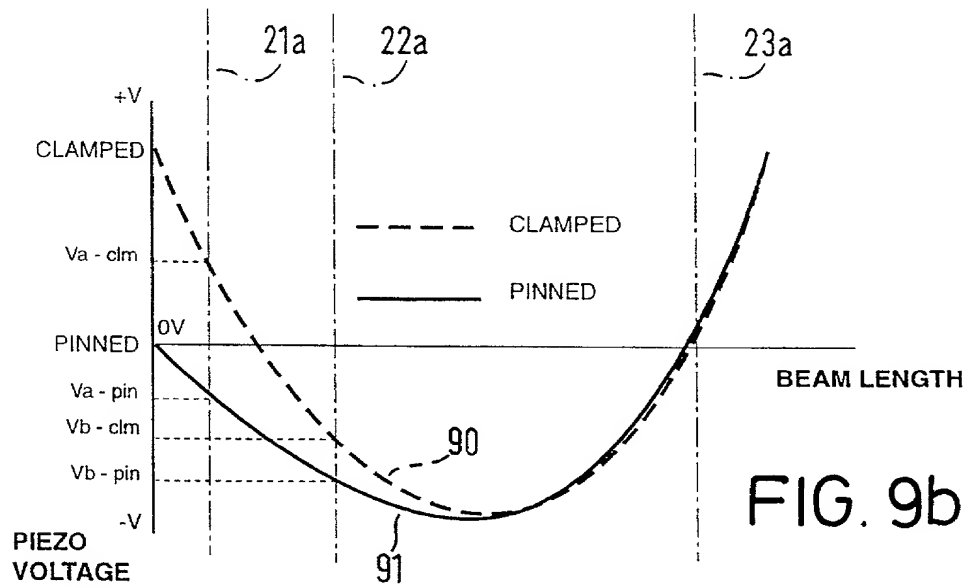
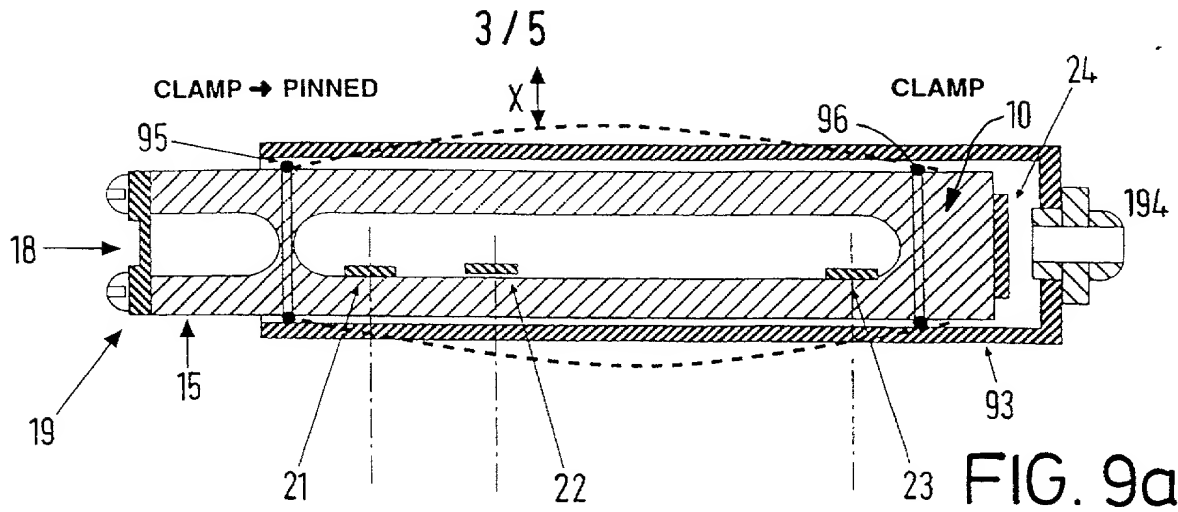
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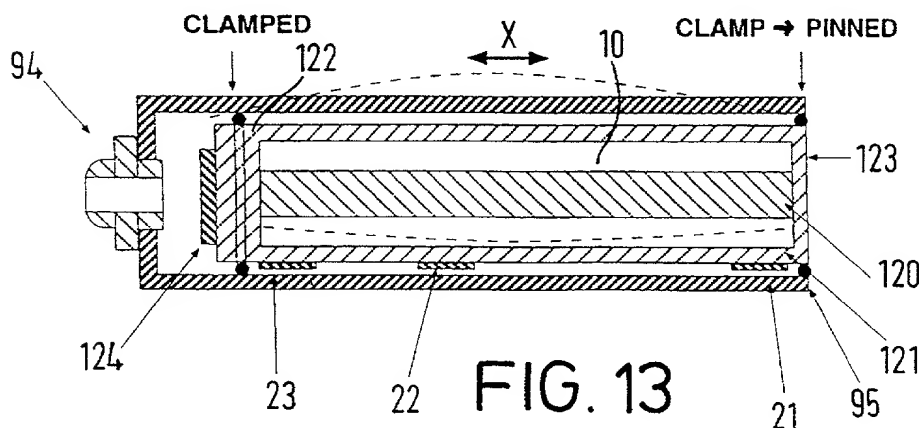
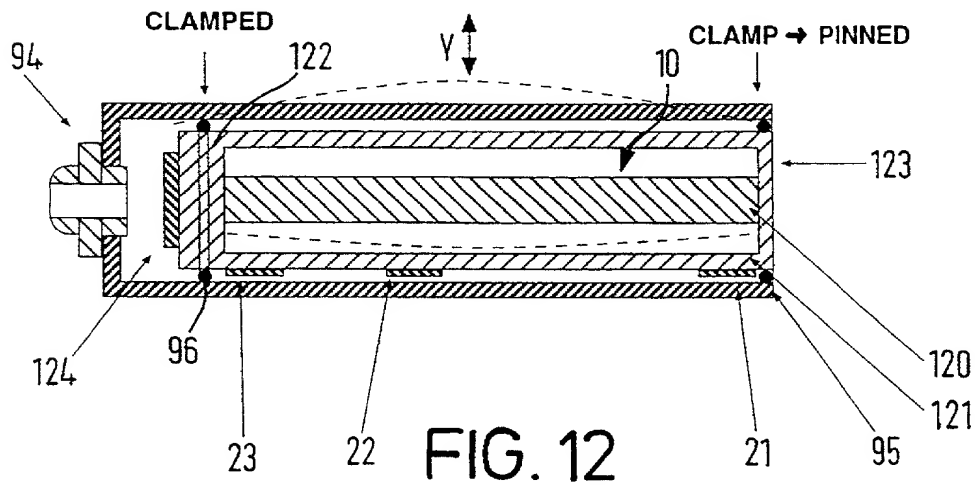
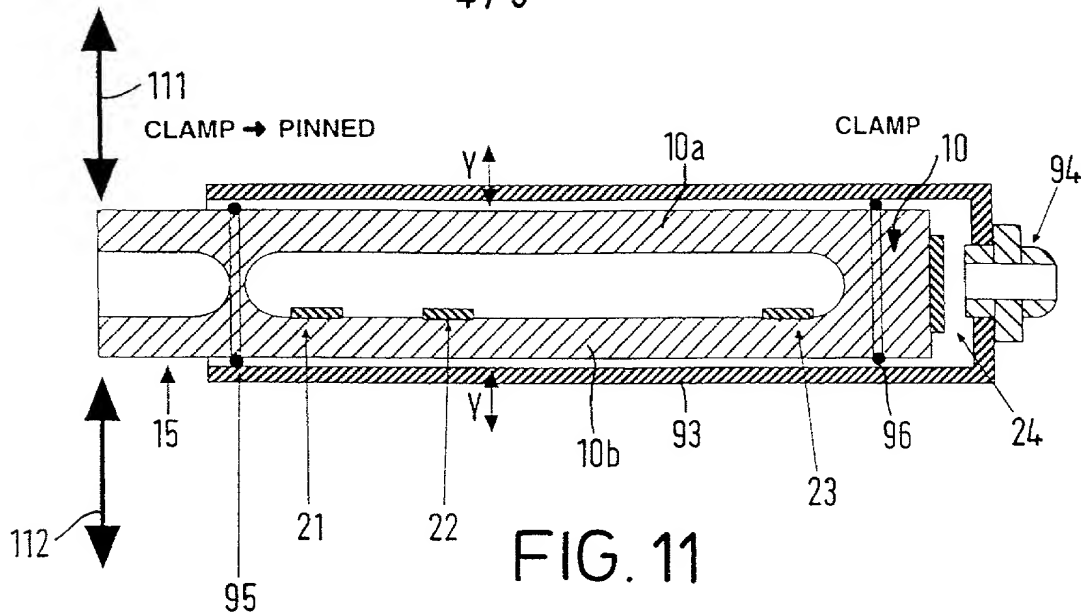
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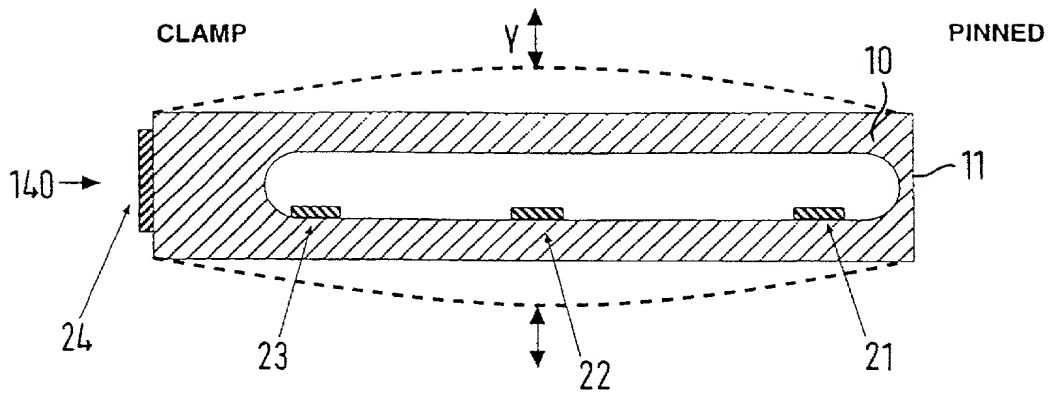


FIG. 14a

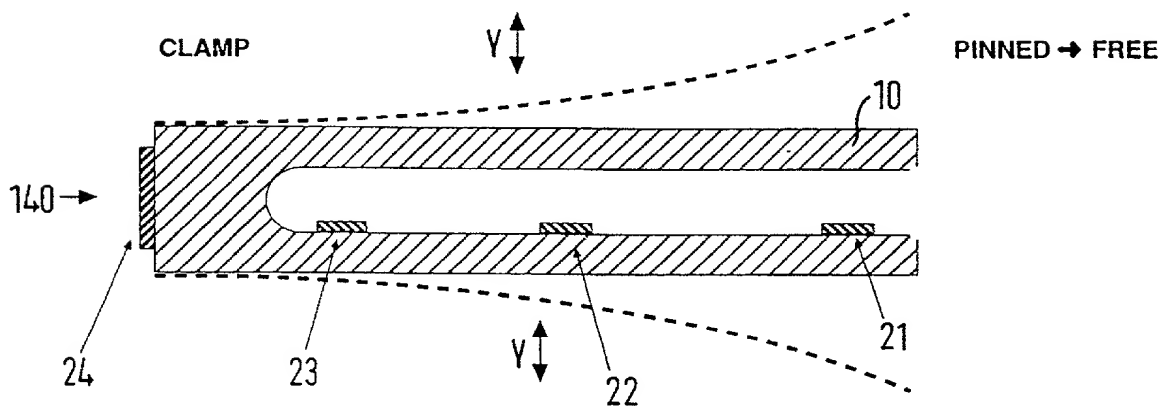


FIG. 14b

RULE 63 (37 C.F.R. 1.63)  
DECLARATION AND POWER OF ATTORNEY  
FOR PATENT APPLICATION  
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DIAGNOSTIC SENSOR

The specification of which (check applicable box(es)):

- ☐ is attached hereto  
☐ was filed on

as U.S. Application Serial No.

(Atty Dkt. No.)

☒ was filed as PCT International application No. \_\_\_\_\_  
and (if applicable to U.S. or PCT application) was amended on \_\_\_\_\_

PCT/GB99/02160

on 6 July 1999

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed or, if no priority is claimed, before the filing date of this application.

Priority Foreign Application(s):

Application Number

Country  
Great Britain

Day/Month/Year Filed  
15 July 1998

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

Application Number

Date/Month/Year Filed

I hereby claim the benefit under 35 U.S.C. 120/365 of all prior United States and PCT international applications listed above or below and, insofar as the subject matter of each of the claims of this application is not disclosed in such prior applications in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose material information as defined in 37 C.F.R. 1.56 which occurred between the filing date of the prior applications and the national or PCT international filing date of this application.

Prior U.S./PCT Application(s):

Application Serial No.

Day/Month/Year Filed

Status: patented  
pending, abandoned

PCT/GB99/02160

6 July 1999

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further: that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. And on behalf of the owner(s) hereof, I hereby appoint NIXON & VANDERHYE P.C., 1100 North Glebe Rd., 8th Floor, Arlington, VA 22201-4714, telephone number (703) 818-4000 (to whom all communications are to be directed), and the following attorneys thereof (of the same address) individually and collectively owner's/owners' attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent: Arthur R. Crawford, 25327, Larry S. Nixon, 25640; Robert A. Vanderhye, 27076; James T. Hosmer, 30184; Robert W. Faris, 31352; Richard G. Besha, 22770; Mark E. Nusbaum, 32348; Michael J. Keenan, 32106; Bryan H. Davidson, 30251; Stanley C. Spooner, 27393; Leonard C. Mitchard, 29009; Duane M. Byers, 33363; Jeffry H. Nelson, 30481; John R. Lastova, 33149; H. Warren Burnam, Jr. 29366; Thomas E. Byrne, 32205; Mary J. Wilson, 32955; J. Scott Davidson, 33489; Alan M. Kagen, 36178; Robert A. Molan, 29834; B. J. Sadoff, 38663; James D. Berquist, 34776; Updeep S. Gili, 37334; Michael J. Shea, 34725; Donald L. Jackson, 41090; Michelle N. Lester, 32331; Frank P. Presta, 19828; Joseph S. Presta, 35329. I also authorize Nixon & Vanderhye to delete any attorney names/numbers no longer with the firm and to act and rely solely on instructions directly communicated from the person, assignee, attorney, firm, or other organization sending instructions to Nixon & Vanderhye on behalf of the owner(s).

1 Inventor's Signature: J. G. [Signature] Date: 26/01/01  
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FOR ADDITIONAL INVENTORS, check box ☐ and attach sheet with same information and signature and date for each.